Aging model for Meteosat First Generation VIS Band and the Normalization to Meteosat-7

Ilse Decoster, N. Clerbaux, E. Baudrez, S. Dewitte, A. Ipe, S. Nevens, A. Velazquez

Royal Meteorological Institute of Belgium (RMIB)
Satellite Application Facility on Climate Monitoring (CM SAF)
Vrije Universiteit Brussel (VUB)

Fall CERES Science Team Meeting
2011, October 4 - 6, Livermore, CA USA

Outline

Meteosat First Generation (MFG)

MVIRI : **M**eteosat **V**isible and **I**nfra **R**ed **I**mager

- Only the narrow band imager MVIRI onboard of the Meteosat First Generation satellites

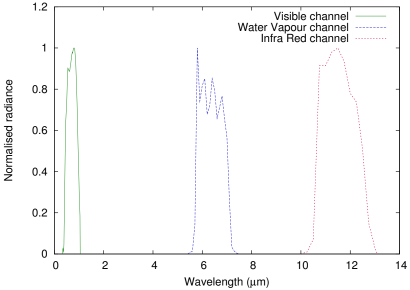
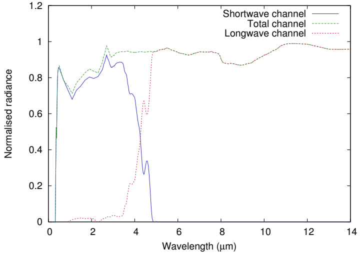


Figure: *Normalized spectral response curves for MVIRI channels (given here are the curves for Meteosat-7)*

Meteosat Second Generation (MSG)

SEVIRI : **S**pinning **E**nhanced **V**isible and **I**nfra **R**ed **I**mager
GERB : **G**eostationary **E**arth **R**adiation **B**udget instrument

- Since 2004, the Meteosat Second Generation satellites carry next to the narrow band (NB) imager SEVIRI also a broad band (BB) instrument called GERB
- In a geostationary orbit, GERB measures the Earth Radiation Budget through 2 broad band channels



- RMIB is part of the GERB consortium

Timeline Meteosat Satellites: 1977 - 2011

- MFG carrying narrow band imager MVIRI
- MSG carrying narrow band imager SEVIRI
  + broad band imager GERB

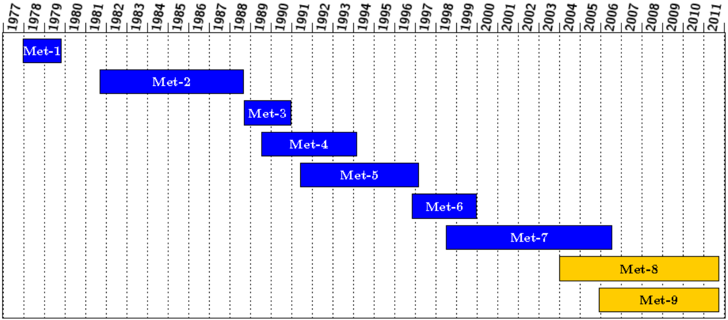


Figure: *Operational time around 0° for all Meteosat satellites sent to space so far*

Ultimate goal: Create GERB-like data for full Meteosat First Generation database

An empirical NB-to-BB conversion algorithm has been developed at RMIB to use (NB) SEVIRI to create (BB) GERB-like data to fill in the gabs in the GERB database

$\Rightarrow$ Same algorithm can be used to create GERB-like data from MVIRI for the MFG satellites, where the overlap between the MVIRI data from the last MFG satellite (Meteosat-7) and the GERB data from the first MSG satellite (Meteosat-8) will be used

Outline

Aging of MFG satellites - the problem

First there is another issue to solve:

the degradation process of the visible channel

- Outgassed material from the space craft can be photodeposited on the mirrors of the instrument due to UV-radiation from the Sun
- Problem seems to be much bigger for MVIRI (MFG) than for GERB (MSG)
- Needed a model to correct for this on the full Meteosat First Generation database before starting with the creation of GERB-like data

Aging of MFG satellites - current state

Current EUMETSAT calibration method for VIS band uses a constantly increasing calibration coefficient in time to correct for aging

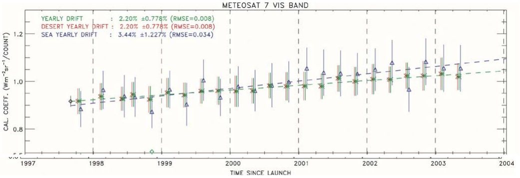


Figure: *Calibration coefficient Meteosat-7 (Govaerts et al. 2004).*

Validation of this method however showed an in-fly change of the spectral response with a stronger degradation effect for shorter wavelengths: **spectral darkening**

Aging of MFG satellites - spectral response

In this work the calibration coefficient was kept constant at the value at launch (unlike the EUMETSAT method) and the **temporal variation of the spectral response** was modeled:

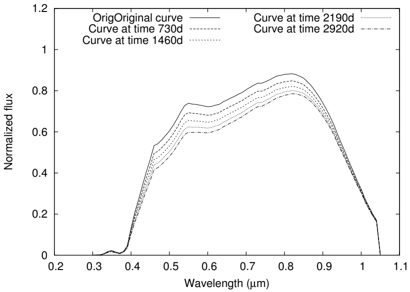


Figure: *Spectral response curve of Meteosat-7 with aging correction after several time steps.*

Aging of MFG satellites - the model

$$\phi(\lambda, t) = \phi(\lambda, 0)\left(e^{-\alpha t} + \beta\left(1 - e^{-\alpha t}\right)\right)\left(1 + \gamma t(\lambda - \lambda_0)\right)$$

- Grey degradation: $e^{-\alpha t} + \beta\left(1 - e^{-\alpha t}\right)$
  - α: decay rate of grey degradation
  - β: asymptotic sensitivity of the mirror for $t \to \infty$
- Spectral degradation: $1 + \gamma t(\lambda - \lambda_0)$
  - γ: decay rate of spectral degradation

Outline

Time Series - choosing targets

To model the parameters, time series for different targets in the Meteosat FOV are used and confronted to the model

- Both cloudy and clear sky time series
- Look for **stable sites**:
  - stable clear sky sites have lowest standard deviation in the total series of images
  - stable cloudy sites are chosen amongst the highly convective clouds, so the highest reflectance values
- Clear sky time series for **different scene types**
  - Scene types used: bright vegetation, dark vegetation, bright desert, dark desert and ocean

Time Series - units

Time series are expressed in reflectance ratio:

- **Value V** of original images in counts $[DC]$
- **Radiance L** obtained using a constant calibration C:
  L = C * (V - offset) $[W/(m^2\, sr)]$
- **Reflectance** ρ obtained as:
  ρ = L / (Irr * cos(SZA) * π * (d)^2)
- **Reflectance ratio** obtained by dividing the reflectance with a simulated reflectance and multiplying with a narrow band (NB) to broad band (BB) correction
  - NB to BB correction through a NB to BB fit of simulated reflectance values: $\rho_{BB} = a + b\,\rho_{NB}$

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Time Series - original

- Obtain 6 time series: 1 cloudy and 5 clear sky time series using 1 image each day at noon, averaged in time over 10 days

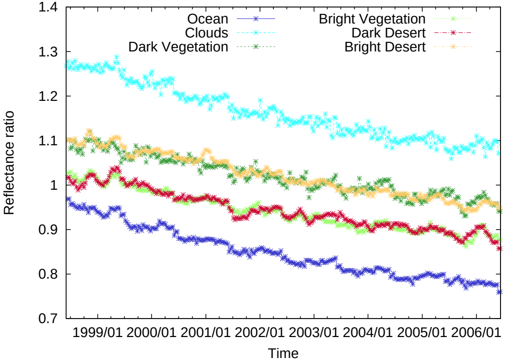

Figure: *Original time series for Meteosat-7.*

Time Series - correction

The aging correction is done in the following way:

- Theoretically NB and BB radiances look like this:

$$L_{NB} = \int_0^\infty L(\lambda)\,\phi(\lambda, t)\,d\lambda$$
$$L_{BB} = \int_0^\infty L(\lambda)\,d\lambda$$

- With simulated radiances $L(\lambda)$ for each different scene type, we can create simulated NB and BB radiances $L_{NB,sim}$ and $L_{BB,sim}$

- A linear relation between these two gives us different (a,b) values for each time step and scene type:

$$L_{BB,sim} = a(t) + b(t)\,L_{NB,sim}(t)$$

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Time Series - correction (2)

- These (a,b) values can now be used on the time dependent narrow band MVIRI observations to create "observed" broad band radiances

$$L_{BB} = a(t) + b(t)\, L_{obs}(t)$$

- For each different set of parameters (α,β,γ) in the model for $\phi(\lambda, t)$, a different $L_{NB,sim}$ is created and a different set of (a,b) values leads to a different broad band radiance

$$L_{NB,sim} = \int_0^\infty L(\lambda)\, \phi(\lambda, t)\, d\lambda$$

- In the end, we look for the model parameters (α,β,γ) that lead to the set of (a,b) values that give horizontal not degrading broad band time series

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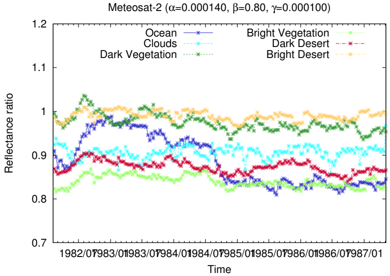
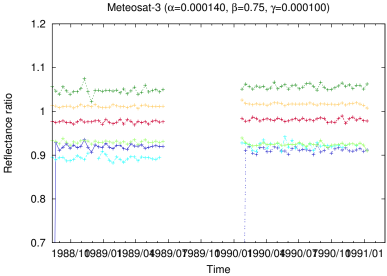
Outline

Results - Meteosat-2 & 3





Parameters are:

$\alpha = 0.000140 \text{ days}^{-1}$

$\beta = 0.80$

$\gamma = 0.00010 \text{ days}^{-1} \mu m^{-1}$

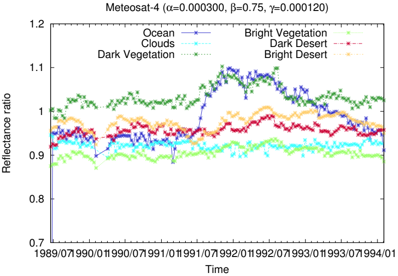
Parameters are:

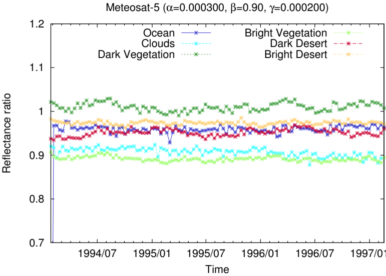
$\alpha = 0.000140 \text{ days}^{-1}$

$\beta = 0.75$

$\gamma = 0.00010 \text{ days}^{-1} \mu m^{-1}$

Results - Meteosat-4 & 5





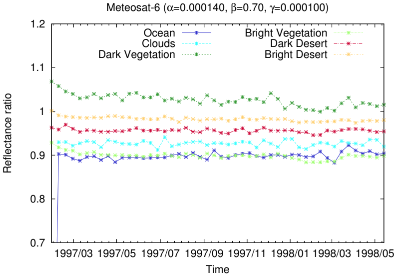
Parameters are:

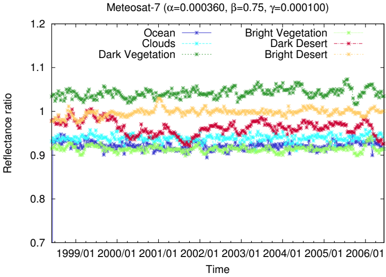
$$\alpha = 0.000300 \text{ days}^{-1}$$
$$\beta = 0.750000$$
$$\gamma = 0.00012 \text{ days}^{-1} \mu\text{m}^{-1}$$

Parameters are:

$$\alpha = 0.00030 \text{ days}^{-1}$$
$$\beta = 0.90$$
$$\gamma = 0.00020 \text{ days}^{-1} \mu\text{m}^{-1}$$

Results - Meteosat-6 & 7





Parameters are:

$\alpha = 0.00014$ days^{-1}

$\beta = 0.70$

$\gamma = 0.00010$ days$^{-1}\mu$m^{-1}

Parameters are:

$\alpha = 0.00036$ days^{-1}

$\beta = 0.75$

$\gamma = 0.00010$ days$^{-1}\mu$m^{-1}

Results - full MFG database

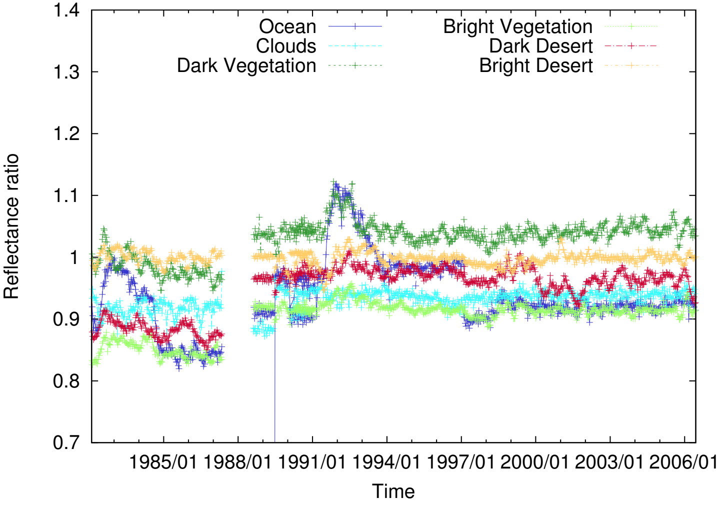


Figure: *Time Series for all Meteosat First Generation satellites*

Outline

Conclusions

- Final goal would be to extend the GERB database of MSG data with GERB-like data from the MVIRI instrument on board of the MFG satellites
- Ageing model was created to correct for ageing effects
- Accuracy of 6% for dark vegetation, 3% for bright desert, 8% for clouds, 4% for bright vegetation, 7% for dark desert and 21% for ocean was reached for the Meteosat-3 till -7 time series.
- Results on Meteosat-2 are not satisfying, still needs to be investigated
- A normalisation to Meteosat-7 was already done as a first step towards the empirical NB-to-BB technique